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54 **Analog multiplexer.**

57 A multiplex system wherein each of the multiplex circuits includes a hold switch (Φ_{HOLD}) and hold capacitor (C_{HOLD}), a standard class A differential amplifier (11) with constant feeding current source, a multiplex switch ($\Phi_{N-1...}$) to selectively isolate each multiplex circuit from the common multiplex line and a second current source (TURBO) supplying much larger current than the constant feeding current source selectively couplable in parallel with the constant feeding current source to the differential amplifier during periods when the differential amplifier is coupled to the common multiplex line.

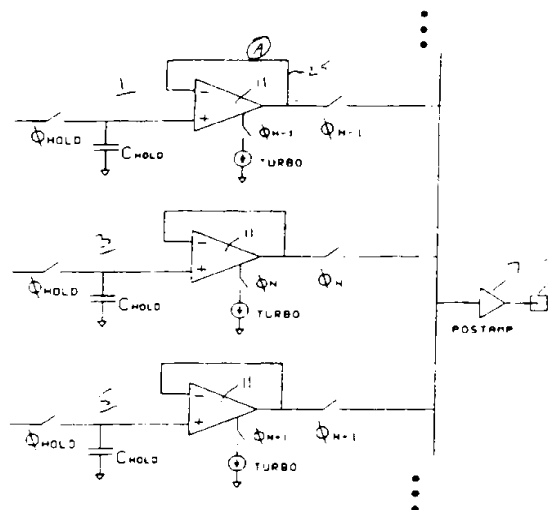


Figure 2. MUX circuit with high power switchable current source.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to high performance analog multiplexers.

BRIEF DESCRIPTION OF THE PRIOR ART

When large quantities of analog data are generated on chip, such as in the case of a focal plane array (FPA), it is necessary to time-domain multiplex (TDM) the signals so that the data can be read serially off chip. With the recent and continuing improvements in detector performance (use of photodiodes such as vertically integrated photodiodes (VIP) instead of photocapacitors, such as vertically integrated metal insulator semiconductor (VIMIS)), the performance of the CMOS circuits that process the detector output also require considerable improvement in order to make full use of the improved detectors.

One standard analog multiplex solution has been the use of a common load source follower multiplexer. A two transistor source follower amplifier is used with a multiplexing switch in each branch of the circuit. The current source transistor of the amplifier is common to all of the input transistors in each of the branches and therefore constantly supplies power to only the branch in use, which minimizes the power consumption. This configuration has two serious second order problems and at least a half dozen performance deficiencies, among these being scan direction crosstalk and positive feedback which causes the amplifier to run significantly slower than predicted.

Another solution is to use one operational amplifier per branch (5 transistor differential amplifier in unity gain mode, for example). This delivers the performance necessary but uses excessive power since each multiplex stage is using full power at all times. Minimizing power consumption is always desirable, but when working at cryogenic temperature, it is absolutely necessary.

It is therefore apparent that an improved analog multiplexer which eliminates one or more of the deficiencies of the prior art analog multiplexer is highly desirable.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a high performance multiplexer circuit on a single chip which holds the large quantities of data generated by the infrared (IR) detectors and samples each detector serially, feeding the information into a post amplifier to be read off chip for further signal processing. The circuit provides low fixed pattern noise, low power requirement, high linearity, high speed, requires minimum chip area, has no second

order effects, has no DC level shift, is stable and easy to implement.

Briefly, the multiplexer circuit comprises a post amplifier to which is coupled a separate circuit for each detector. Each of the separate circuits comprises a hold switch between the associated detector and a hold capacitor to store the charge received from the associated detector. The hold capacitor is coupled to a standard five transistor class A differential amplifier configured in unity gain mode and having a separate switchable high power current source selectively coupled thereto and a multiplex switch for selectively coupling the separate circuit to the post amplifier. A typical focal plane array (FPA) may have, for example, 240 detector elements with a separate circuit associated with each detector element, each of the separate circuits being multiplexed serially in some predetermined order to provide serial signals to the postamplifier.

In operation, the hold switch is closed and opened periodically to store the charge received from the associated detector on the hold capacitor. Then the multiplex switch and the associated switch to the high current source in each separate circuit are simultaneously closed, this closing action taking place serially from separate circuit to separate circuit to provide the serial multiplexed output to the postamplifier.

A significant feature of the invention is the addition to the standard differential amplifier circuit of the selectively switchable high power current source (or turbo current source) in parallel with the standard current source which forms a part of the standard differential amplifier circuit. The turbo current source significantly reduces the power requirement of the differential amplifier but also maintains the high speed thereof. The differential amplifier only requires the high power when driving the multiplex line (high parasitic capacitance). Therefore, switching on and off of the high current permits the fast operation from a very low power circuit. The standard current source of the differential amplifier sinks just enough current to keep the amplifier from floating to unknown states when the multiplex switch and turbo switch are off or in the open condition.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a circuit diagram of a typical prior art multiplex circuit from three of plural detectors; FIGURE 2 is a block diagram of a multiplex circuit in accordance with the present invention; FIGURE 3 is a circuit diagram of the circuit of FIGURE 2; and FIGURE 4 is a timing diagram for use in conjunction with the circuit of FIGURES 1, 2 and 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIGURE 1, there is shown a circuit diagram of a portion of a multiplex circuit in accordance with the prior art as discussed hereinabove. Charge from a detector is stored on the hold capacitor C_{HOLD} while the hold switch ϕ_{HOLD} is closed with a readout being provided to the multiplex output upon opening of switch ϕ_{HOLD} followed by closing of multiplex switch ϕ_{MUX} . This circuit presents many problems, one of which is the fact that there is a stray capacitance between gate and source, C_{gs} , and between base and source, C_{bs} . Capacitance C_{bs} stores the signal value on the intermediate multiplex node at the drain of the transistor so that, when the next signal value arrives, a portion of the signal is fed through capacitance C_{gs} and onto the hold node at the gate of the transistor. This will appear to be a scan direction crosstalk. A second problem occurs when switch ϕ_{MUX} is closed wherein capacitance C_{gs} creates a positive feedback loop which causes the circuit to operate much slower than predicted and changes the voltage held on capacitor C_{HOLD} .

Referring now to FIGURE 2, there is shown a block diagram of a multiplexing circuit in accordance with the present invention. The multiplexing circuit includes a plurality of separate circuits 1, 3 and 5, each connected to a postamplifier 7, the output of which is coupled to a chip pad 9. Each of the circuits 1, 3 and 5 is coupled to an associated detector (not shown) and includes a hold switch ϕ_{HOLD} downstream from the associated detector and a hold capacitor C_{HOLD} downstream from the hold switch and coupled to the positive input of a unity gain differential amplifier 11. Each differential amplifier 11 is selectively coupled to a high current source or turbo via a switch ϕ_{N-1} in circuit 1, switch ϕ_N in circuit 3, switch ϕ_{N+1} in circuit 5, etc. for the remaining separate circuits. A feedback loop is provided between the output of each differential amplifier 11 and the negative input thereof. The output of each differential amplifier 11 is coupled to the postamplifier 7 via a switch ϕ_{N-1} in circuit 1, switch ϕ_N in circuit 3, switch ϕ_{N+1} in circuit 5, etc. for the remaining separate circuits which is operated simultaneously with the switch with identical reference number coupled to the turbo.

Referring now to FIGURE 3, there is shown the separate circuit 3 of FIGURE 2 in greater detail wherein identical reference characters refer to identical circuit elements. As can be seen, the differential amplifier 11 of FIGURE 2 includes the + and - inputs at the gates of transistors 21 and 23 respectively and includes transistors 21, 23, 27, 29 and 31 which form a standard textbook differential amplifier aside from the turbo transistor 33 which is explained hereinbelow. The feedback path 25 is shown between the drain and gate of transistor 23. Additional current mir-

ror transistors 27 and 29 are coupled to a voltage source V_{DD} in standard manner. Transistor 31 is the standard current source for the differential amplifier 11 and transistor 33 is the turbo or high current source and provides much greater current to the differential amplifier than does transistor 31 by a factor of about 100. The current in transistor 31 is set so that node 35 settles to its final value while the ϕ_{HOLD} switch is closed. This is generally several microamperes (μA). The current in transistor 33 is set so that the multiplex line 37 settles to its final value during ϕ_N . As noted above, the current ratio between transistors 31 and 33 is generally about 100, however this ratio can be altered as required. This ratio is generally accomplished by making transistor 33 much larger than transistor 31 on the same chip. The transistors 31 and 33 are biased into the conducting state by the same bias input, however transistor 31 will immediately conduct when appropriately biased whereas transistor 33 will conduct only when appropriately biased and with switch ϕ_N closed. The amplifier 11 is unity gain so the output of thereof should track the condition of the hold capacitor C_{HOLD} .

In operation, and with reference to FIGURES 2, 3 and 4, current from the detectors (not shown) is constantly being applied to input V_{IN} . The switches ϕ_{HOLD} in each of the separate circuits are closed in a predetermined succession and then opened as shown in the timing diagram of FIGURE 4 to charge the associated hold capacitor C_{HOLD} and then isolate that capacitor from the associated detector. The charge on hold capacitor C_{HOLD} is applied to the + input of the differential amplifier 11. Meanwhile, transistor 31 is conductive due to the bias on the gate thereof provided by an on-chip bias generator (not shown) and constantly applied to the gate. Transistor 33 is capable of conducting due to the bias thereon but for the fact that switch ϕ_N is open. Now, when switches ϕ_N are closed, the high current from the turbo 33 is applied to the amplifier 11 and the circuit 3 is coupled to the postamplifier 7 via now closed multiplex switch ϕ_N . Switches ϕ_N then close and the cycle is repeated for the next separate circuit, etc. in standard manner.

It can also be seen that if the circuit is to settle, for example to 5 volts in 100 nanoseconds, and the stray capacitance in the circuit is, for example, 6 pf, then about 300 microamperes ($I = C(dv/dt)$) of current will be required in transistor 33. Assuming a 10 volt power supply and 240 detectors, the power requirement is quite large, about 720 milliwatts. Accordingly, the introduction of the large current supply from the turbo transistor 33 periodically rather than continually as described above provides a substantial power saving (about 10 milliwatts) and minimizes heat generation. Furthermore, without the turbo high current source 33 a great deal of power would have to be consumed (assuming 240 separate circuits were being used simultaneously at about a 4 MHz data rate and

6 pf capacitance on the multiplex line) in order to provide sufficiently high operating speeds (about 100 nanoseconds of settling). The high power is required only when the multiplex switch ϕ_N, \dots is closed which, in the case of 240 separate circuits, is only 1/240th of time. This is especially important in the case of focal plane arrays wherein the array is maintained at cryogenic temperatures, generally about -196°C (77°K) and wherein the heat generated by the multiplexer will have a detrimental effect on the array performance.

The high current is applied to each of the differential amplifiers only for the short period when the switch coupling the turbo 33 to the associated differential is closed, thereby providing the power saving. It follows that the speed advantages of a high current amplifier are present without the high power disadvantages.

Though the invention has been described with respect to a specific preferred embodiment thereof, many variations and modifications will immediately become apparent to those skilled in the art. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

Claims

1. A multiplex circuit comprising:
 - an amplifier having a first current source continually coupled therein; and
 - a second current source providing substantially higher values of current to said amplifier than said first current source, said second current source selectively coupled to said amplifier.
2. The system of claim 1, wherein said amplifier is a differential amplifier and includes a first input terminal, a second input terminal, an output terminal and a feedback path between said output terminal and said second input terminal, further including a charge storing means coupled to said first input terminal for storing charge applied to said first input terminal from a remote source.
3. The system of claim 1 or claim 2, wherein each said charge storing means is selectively coupled and uncoupled from said remote source.
4. The system of any of claims 1 to 3, wherein said second current source is coupled in parallel with said first current source.
5. The system of any of claims 1 to 4, further including a postamplifier and a switch selectively coupling and uncoupling said amplifier and said post-amplifier simultaneously with the coupling and uncoupling of said second current source and said amplifier.
6. The system of any preceding claim and further comprising a plurality of multiplex circuits, wherein the second current source of each of said separate circuits being coupled to their associated amplifier at selectively spaced, non-overlapping time periods.
7. The system of any preceding claim, wherein the charge storage means comprises a capacitor.
8. The system of claim 6 or claim 7, further comprising a multiplex switch for selectively isolating each circuit from a common multiplex line.

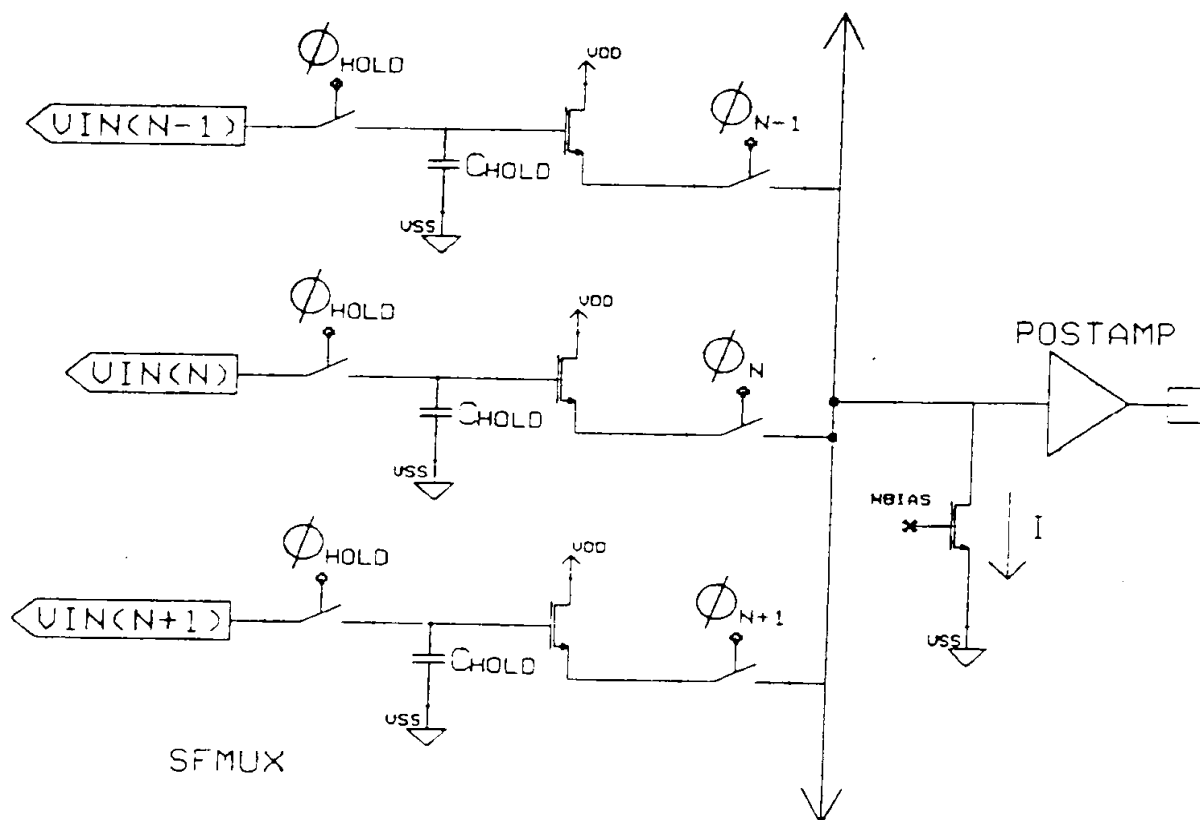


Fig 1

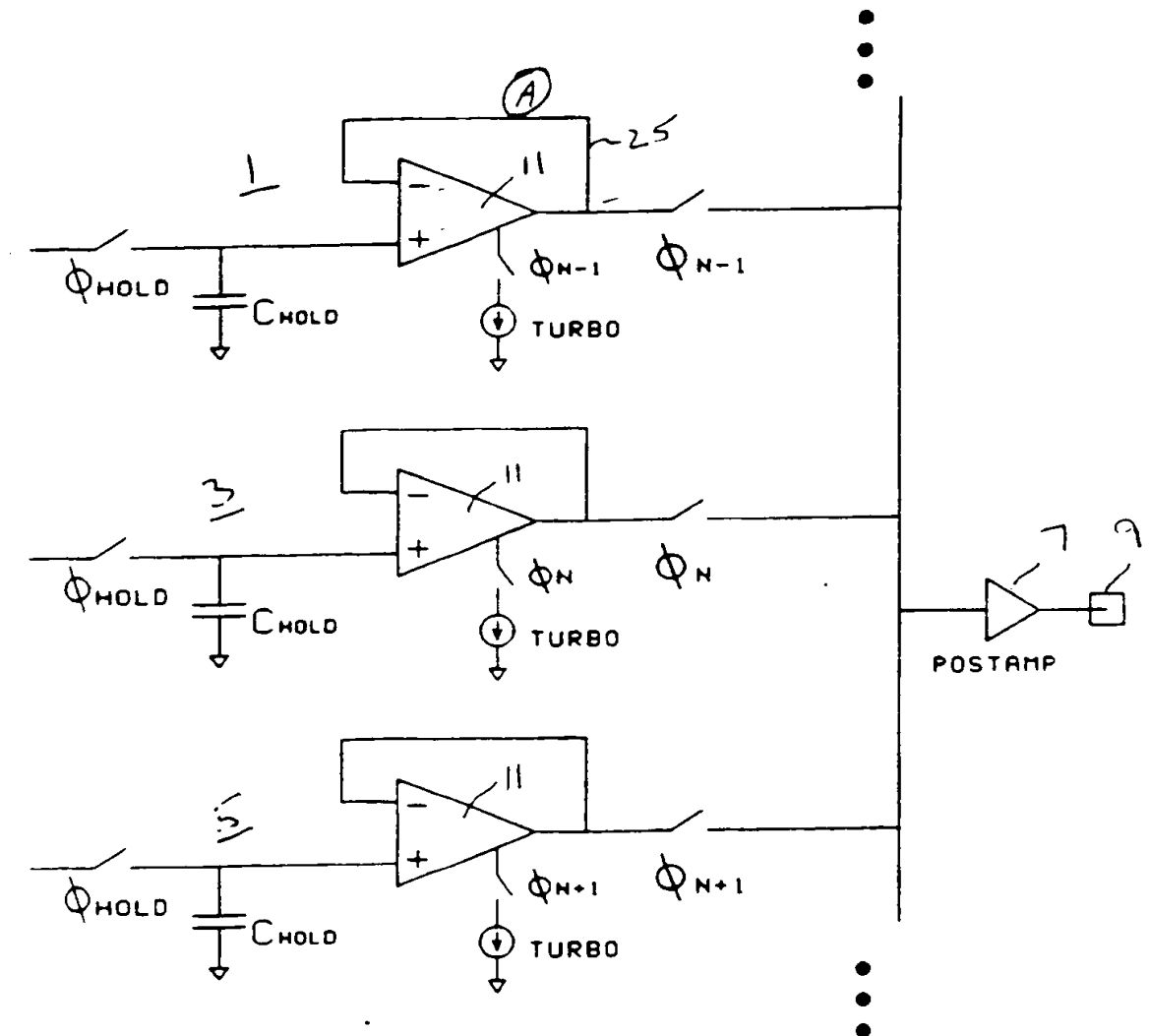


Figure 2. MUX circuit with high power switchable current source.



Figure 4.



(12)

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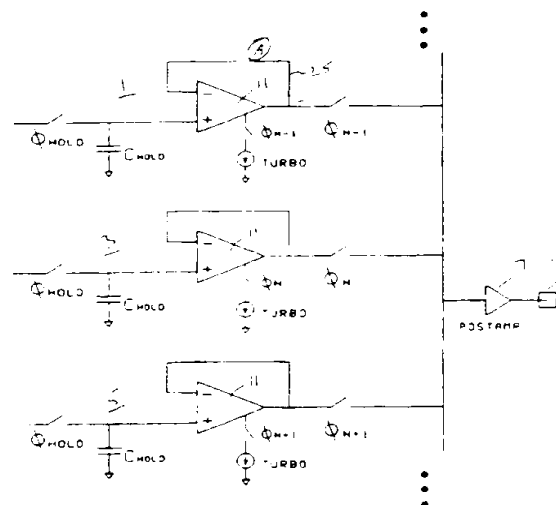


Figure 2. MUX circuit with high power switchable current source.



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 6742

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	US-A-4 999 519 (G. KITSUKAWA ET. AL.) * column 7, line 14 - column 8, line 66; figures 5,6 *	1	H03K17/00
Y	---	2-8	
Y	EP-A-0 398 778 (THOMSON CSF SCPI) * page 3, column 4, line 33 - page 4, column 5, line 24; figure 5 *	2-8	
X	US-A-4 321 488 (G. SRIVASTAVA) * column 2, line 37 - column 5, line 2; figures 1,2 *	1	
A	US-A-4 876 519 (C. DAVIS ET. AL.) * column 3, line 27 - column 4, line 7; figure 4 *	1	
A	FR-A-2 590 697 (SGS MICROELECTRONICA) * figures 1,2 *	1	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			H03K G11C H03F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 18 November 1994	Examiner Butler, N
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document</p>			

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